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Sowing date and weed competition effects on growth, phenology and yield of three white bean (*Phaseolus vulgaris* L.) cultivars

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Key words: Bean, CGR, LAI, height, interference.

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Abstract

Suitable sowing date and weed management are the most important factors in crop production. In order to study the effect of sowing date and weed competition on some ecophysiological traits of different white bean cultivars a factorial experiment based on randomized complete block design with three replications was carried out in 2009 in Semirom, Iran. The treatments consisted of three sowing dates (May10, May 25 and June 9) and three white bean cultivars (Shekoofa, Pak and Daneshkade) and two levels of weed infestation (weedy and weed free). Result showed that earlier sowing date, due to longer growing season, increased height, number of branches, number of days from sowing to flowering and the flowering period. The most leaf area index, leaf area duration and crop growth rate was obtained in May 10 sowing date. Weed interference significantly decreased leaf area index (41.6%), leaf area duration (37.7%) and crop growth rate (37.3%). Yield loss due to weed competition was more in later sowing dates than others. Shekoofa cultivar had higher grain yield because of higher leaf area index, more leaf area duration and more crop growth rate.

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Introduction

According to yield losses due to weeds competition, their management has been inseparable part of agricultural practices during all the times (Carvalho and Christoffolet, 2008).Bean (*Phaseolus vulgaris* L.) with high protein content (20-50%) is the most important member of legume family that is very sensitive to weed interference because of short growing period. weed competition can reduce bean yield by 70% (Carvalho and Christoffoleti, 2008). Results of Chikoye *et al.*, (1996) indicated that weed interference reduced biomass, pod number and leaf area index of bean severely. Ebrahimi *et al.*, (2012) found that soybean leaf area index reduced about 53% as affected by weed interference. There is a correlation between grain yield loses, leaf area index (LAI) and leaf area duration (LAD) and it can be assumed that weeds decrease crop yield mainly by reducing these two parameters. Van Acker *et al.*, (1993) by evaluating the competition between soybean and natural weeds reported that crop growth rate and total dry matter reduction was attributed to the reduction of leaf area.

Appropriate weed management techniques, such as integrated weed management, can reduce the effect of weed damage. Regards to extension of weed resistance to herbicides and environmental distractive effect of their usage, improvement of ecological and agronomical strategies can be proposed as an immune and economical way for weed management (Dunan *et al.*, 1995). Agronomic practices, such as suitable sowing date management, can be an ecological strategy to improve crop competition ability and so weed growth prevention (Fernandez *et al.*, 2002). Sowing date can affect on crop growth due to its influence on weed density. Avarseji *et al.*, (2010) by comparing the effect of three sowing dates (April 25, May 10 and May 25) on bean in Mashhad, Iran, observed that delay in bean planting increased weed dry weight and enhanced damage to bean yield. Ghanbari Motlagh *et al.*, (2011) with evaluating two sowing dates (May 20 and June 3) on weed competition with three red bean variety also stated that delay in sowing decreased dry weight and competition ability of weed. Planting varieties with high competitive ability is another ecological and sustainable strategy to reduce weed damage. Amini *et al.*, (2009) with evaluation of competitive ability of three cultivars of red bean (Akhtar, Sayyad and Line D81083) against redroot pigweed (*amaranthus retroflexus*) reported that Sayyad cultivar had the most competitive ability among the red bean cultivars.

Because of few studies about competition ability of white bean varieties in Iran and as mentioned above according the effect of sowing date on weed – crop relationship this study was planned to evaluate the effects of sowing date on growth indices of three white bean cultivars under weed competition for determining the best cultivar and sowing date to achieve maximum grain yield and weed repression in Semirom region.

Materials and methods

This experiment was conducted at a research field in Semirom, Iran (longitude 51° 43́E, Latitude 31° 11́N, 2329 m above sea level) in 2009. Experiment was arranged as factorial based on randomized complete block design with three replications. The treatments were three sowing dates (May 10, May 25 and June 9), three white bean cultivars (Shekofa, Pak and Daneshkade) and two levels of weed competition (weed free and weed infest). Each experimental plot was consisted of five planting rows with 9 m length and 50 cm distance between rows. The distance between plants within each row was 5 cm for three cultivars. In all sowing dates, wet planting was done 3 days after irrigation in soil field capacity condition. The first irrigation was 3 days after seedling emergence and next irrigations carried out once every 6-7 days based on plant requirement, temperature and climate circumstances. Redroot pigweed (*Amaranthus retroflexus* L.) and Common lambsquarters (*Chenopodium album* L.) were dominant weeds in each three sowing dates. In weed free treatment, weed control was conducted since the emergence of cotyledonal leaves throughout the growing season. To determine the bean growth

indices from 30 days after sowing, destructive sampling was accomplished in every 15 days and dry weight and leaf area of samples were measured. Then by using mathematical equation (Yadavi *et al.*, 2007) leaf area index and crop growth rate of bean were calculated. Leaf area duration (LAD) of bean after flowering was calculated as below:

$LAD= ((LAI_1+LAI_2)/2) \times K$

Where LAI_1 and LAI_2 are leaf area indices in flowering and physiological maturing phases, respectively, and K is the gap (days) within them. To determine the Bean development phases, experimental plots had been inspected every day and when 50% the plants of each plot entered to a special development phase, the time had been recorded. At the end of season (September 15 to 21), 3 m of middle of each plot, (4.5 m^2) was harvested for grain yield determination. Data analysis performed by GLM procedure using SAS (ver. 9.1) software and mean comparisons were done using Duncan's multiple range tests at 5% probability.

Results and discussions

Plant Height

The effect of planting date, cultivar and weed competition were significant ($p<0.01$) for plant height but no significant interactions between experimental treatments were seen for this trait (Table 1).

Table 1. Analysis of variance of some white bean cultivars traits affected by sowing date and weed competition.

S.O.V	D.F	Mean squares							
		Height	Number of branches	Max. LAI	LAD	Max.CGR	Sowing to flowering	Flowering duration	Grain yield
Replication	2	156.01	3.17	0.17 ^{ns}	96.07^{ns}	0.33^{ns}	6.50 ^{ns}	0.22^{ns}	11367.27
Sowing date (A)	2	758.81 **	1.78**	2.58 **	3009.85**	57.38**	779.55**	35.05**	4110869.84**
Cultivar (B)	2	582.14**	3.38**	0.68**	411.30^{ns}	5.08**	4.38 ^{ns}	1.05^{ns}	1889023.41**
Competition (C)	1	1113.02**	1.94**	29.28**	19677.59**	615.56**	0.07^{ns}	0.29 ^{ns}	1570528.67**
AB	4	61.24^{ns}	0.12^{ns}	0.10 ^{ns}	71.58^{ns}	0.7 ^{ns}	1.61^{ns}	2.11^{ns}	39050.24^{ns}
AC	2	60.70^{ns}	0.12^{ns}	0.14 ^{ns}	177.06^{ns}	1.03 ^{ns}	0.07^{ns}	0.24^{ns}	95510.47*
BC	2	10.29^{ns}	0.01 ^{ns}	0.02 ^{ns}	31.4^{ns}	0.002 ^{ns}	0.57^{ns}	0.35 ^{ns}	370111.96**
ABC	5	19.20 ^{ns}	0.09 ^{ns}	0.11 ^{ns}	59.81^{ns}	0.90^{ns}	0.53 ^{ns}	0.10 ^{ns}	25689.42^{ns}
Error	33	70.41	0.22	0.06	58.89	0.69	2.84	0.97	26087.41
CV %		14.03	16.05	8.65	9.35	5.99	2.28	11.54	7.86

ns, *,** mean no significant, significant at $p<0.05$ and significant at $p<0.01$ respectively.

According to the mean comparison, delay sowing reduced height of bean plant significantly so that 15 and 30 days delay from primary sowing date, reduced plant height about 8.3 and 12.8 cm, respectively (Table 2). However, between May 25 and June 9 planting dates no significant difference observed for this trait. Means comparison also showed that Daneshkade cultivar had higher height than Shekoofa and Pak cultivars (Table 2). Weed competition caused a reduction in bean plant height (Table 2). Sowing date can affect growth rate and plant height by changing in environmental circumstances such as temperature, day duration and soil available moisture in all of the growing season period. In early planting date, more vegetative development duration and flowering delay, finally caused the vegetative growth enhancement and plant height. In this experiment, accelerated development was observed due to day duration reduction and high temperature and early sowing saw so high plant height. Khalil *et al.*, (2010) also illustrated that delay in broad bean (*Vicia faba* L.) sowing, reduced plant height and maximum and minimum plant height was achieved from planted crop in September 20 and December 27, respectively. They told that early planting in compare with delay planting, gives more opportunities to plants to uptake water and soil nutrient, suitable vegetative growth, effective usage of light and photosynthetic matter production. Most of the differences for plant height occur because their genetic factors and growth traits. This research is similar to other researches about genetic differences for plant height. Zafar *et al.*, (2010) also observed highest height (3.48 m) and lowest height (2.14 m) in sugarcane in complete weeding and weedy treatments, respectively.

Table 2. Mean comparison of some white bean traits as affected by different sowing date, or cultivar or weed competition.

		Height (cm)	Number of branches	Max. LAI	LAD	Max. CGR (g m^{-2} day^{-1})	Sowing to flowering (Day)	Flowering duration (Day)	Grain yield (kg ha^{-1})
Sowing date	May 10	66.8 a	3.3 a	3.3 a	95.9 a	15.7 a	80.0 a	10.2 a	2454.0 a
	May 25	58.5 b	2.9 b	2.8 b	79.7 b	13.7 b	74.4 b	7.7 b	2185.4 b
	June 9	54.0 b	2.7b	2.5 c	70.4 c	12.2 c	66.9 c	7.8 b	1525.3 c
Cultivar	Shekoofa	59.4 b	2.5 b	3.1 a	86.0 a	14.5 a	73.2 a	8.4 a	2375.4 a
	Pak	54.3 b	3.1 a	2.8 b	83.2 a	13.7 b	74.2 a	8.4 a	2055.9 b
	Daneshkade	65.7 a	3.3 a	2.7 b	76.7 b	13.4 b	73.9 a	8.8 a	1730.4 c
Weeds	Weed free	64.3 a	3.1 a	3.6 a	101.1 a	17.3 a	73.8 a	8.5 a	2594.2 a
	Weedy	55.3 b	2.8 b	2.1 b	62.9 b	10.5 b	73.7 a	8.62 a	1515.6 b

Means by at least one similar letters In each column are not significantly different at 5% probability.

Number of branches

Effect of sowing date, cultivar and weed competition was significant ($p<0.01$) for number of branches but no interaction within experimental treatments were significant for this trait (Table 1). There was a reduced trend in number of branches affected by delay sowing, so maximum (3.3) and minimum (2.7) were seen for first and third planting date respectively, although there was no significant difference between second and third sowing dates (Table 2). Means comparison showed that Pak and Daneshkade cultivars produced more branches than Shekoofa cultivar and the difference between Daneshkade and Pak cultivars was not significant (Table 2). Weed competition also reduced number of branches about 10% (Table 2). The more suitable situation for vegetative growth at the first sowing date caused delay in reproductive growth and flowering initiation, therefore in this sowing date both plant height and number of branches were increased. The results of Bastidas *et al.* (2008) on soybean illustrated that by delay sowing, branches development was limited and yield reduction in unsuitable sowing dates caused low grain production. Shamsi (2010) in evaluation of three sowing dates (November 6, 23 and December 6) found that delay planting of chickpea (*Cicer arietinum* L.) reduced number of branches and the lowest (2.2) was achieved at last sowing date. Albeit regards to longer maturity of Daneshkade cultivar in compare with other cultivars, and according to Weaver *et al.*, (1991) results on the basis of this fact that long opportunity is suitable for growth and photosynthetic area production in late maturity cultivars, more number of branches production in this cultivar was predictable. Available space reduction in weedy treatments due to more density can reduce number of branches in bean plant. Mirshekari *et al.*, (2008) showed that maximum (4) and minimum (2) number of branches in canola was belonged to weed free and weed infested situation, respectively.

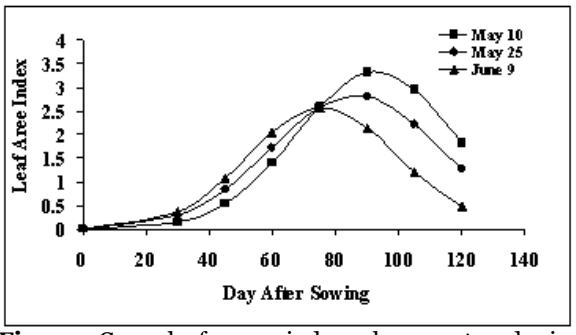

Fig. 1. Crop leaf area index changes trends in different sowing dates.

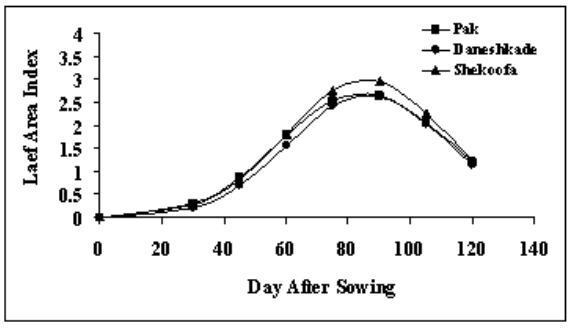

Fig. 2. Leaf area index changes trends in different white bean cultivars.

Leaf Area Index (LAI)

Sowing date, cultivar and weed competition effect on maximum leaf area index (Max.LAI) was significant

($p<0.01$) but the interactions of experimental treatments were not significant for this trait (Table 1). Means comparisons showed that the highest (3.3) and lowest (2.5) Max.LAI were achieved on May 10 and June 9 sowing dates respectively, and this caused to more radiation interception and photosynthetic ability on May 10 sowing date (Table 2). Mean comparison results of Max.LAI also illustrated that there was no significant difference between Pak and Daneshkade cultivars and the highest Max.LAI belonged Shekoofa cultivar (Table 2). Weed competition caused a 41.6% reduction in bean Max.LAI in compare with weed free situation (table 2). Munakamwe (2008) by evaluation the effect of three sowing dates (August 9, September 13 and October 15) on field pea observed that sowing delay decreased LAI due to growth duration reduction. Respect to LAI trend in different sowing dates (Figure 1), it is observed that delay of sowing made a LAI reduction from 75 days after sowing. At first planting date in long growth duration, plants stand in favorable situation and LAI increased by enough heat units reception (growing degree days) and reached to its maximum in flowering stage (90 days after sowing) and after that, the necrosis will initiate due to leaf shading and senescence, so leaf area reduced and finally at harvesting time, leaves approximately dried and fell down. LAI in May 25 and June 9 sowing dates up to 30 days after sowing have coincided together but after that in third sowing date, bean LAI increased with harsher gradient because of shorter growth duration, higher temperature and day duration reduction. LAI in Jun 9 sowing date reached to its maximum sooner than other sowing dates (75 days after sowing) but this maximum had been lower than earlier sowing dates. LAI for third sowing date occurred earlier than previous sowing dates. LAI trends in different cultivars (Figure 2) showed that, in all three cultivars at the first phase up to 40 days after sowing, change was very slow and at this phase Pak cultivar could promote its leaf area index more than two other cultivars. LAI changes were more perceptible at the second phase. In each three cultivars, the upward changes continued up to 90 days after sowing. At this stage, there was not significant different between Pak and Daneshkade cultivars and maximum LAI was belonged to Shekoofa cultivar. At the next stage, which starts after maximizing the LAI, changes of LAI had downward trend in three cultivars and in Shekoofa cultivar decreased with harsher gradient. Concerning to figure 3, LAI changes for weedy and weed free treatments were coincide together up to about 30 days after sowing, indeed this was because of small plants and no competition between bean and weeds but from 30 days after sowing weed infestation caused a sever reduction in white bean LAI and weed interference treatment got to maximum LAI earlier and it showed that canopy has been closed earlier (Figure 3). One of the most obvious effects of weeds on the farm is increasing plant density per unit area. In weed-crop competition condition although the leaves of plant population per unit area increase but crop LAI quickly reduced because of each plant leaf area reduction due to inter-specific and intra-specific competition (Chikoye *et al.*, 1996). Leaf area reduction can decrease photosynthetic active radiation reception and therefore photosynthesis and assimilation will reduce. Grenz *et al.* (2005) by evaluating the effect of environmental conditions and sowing dates on faba bean and orobanche (*Orobanche crenata* L.) competition observed that this weed presence caused a reduction in bean leaf number and leaf area.

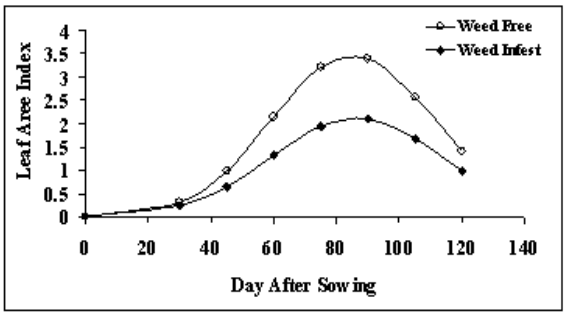

Fig. 3. Leaf area index changes trends affected by weed competition.

Leaf Area Duration (LAD)

The influence of sowing date, cultivar and weed competition was significant ($p<0.01$) for leaf area duration but no interactions of experimental treatment on this trait were significant (Table 1). Mean comparison of sowing date effect on this trait

showed that delay sowing is responsible for bean LAD reduction as maximum and minimum LAD after flowering was achieved at first and third sowing dates, respectively (Table 2). However, Daneshkade cultivar between other cultivars had the lowest LAD and there was no significant difference between Shekoofa and Pak cultivars (Table 2). Weed free caused a 37.7% increase in LAD compared to weed presence (Table 2). LAI and LAD after flowering are the most important traits in plant that indicate the amount of absorbed radiation. LAD is responsible for leaf area stability and rate in all plant growth period. LAD is an important growth index that affects on final crop yield. LAD is dependent on temperature and affected by sowing date (Munakamwe, 2008). Thompson and Siddique (1997) reported that maximum grain yield of legumes is dependent on LAD. By sowing delay, LAD is reduced significantly because of growth season duration and day duration reductions. Irshad and Cheema (2002) in a rice growth indices investigation in competition with barnyard grass (*Echinochloa crus-galli* L.) reported that maximum and minimum rice LAD was belonged to weed free and weedy treatments respectively.

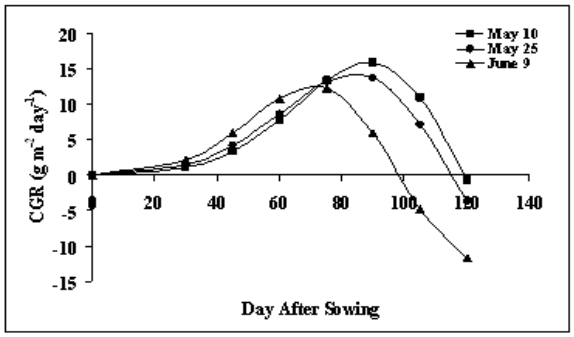

Fig. 4. Bean crop growth rate changes trends in different sowing dates.

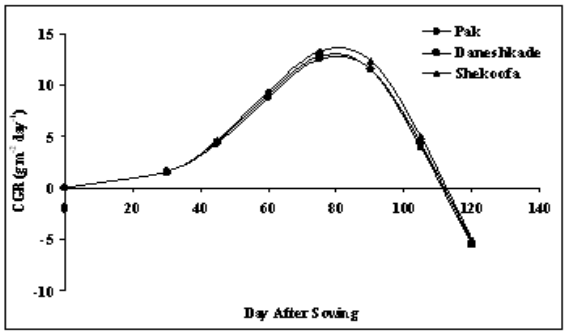

Fig. 5. Crop growth rate changes trends in different white bean cultivars.

Crop Growth Rate (CGR)

Analysis of variance (Table 1) showed that sowing date, cultivar and weed competition have had significant effect on maximum crop growth rate (Max.CGR) of white bean, but no interactions of experimental treatments was significant on this trait (table 1). One-month delay of planting (planting on June 9) caused a significant reduction (22.2%) in Max.CGR than planting on May 10 (Table 2). Mean comparisons of cultivars illustrated that Max.CGR was belonged to Shekoofa cultivar (15.7 g m^{-2} day^{-1}) and there was no significant difference between Pak and Daneshkade cultivars (Table 2). Shekoofa cultivar due to semi-indeterminate and standing growth form, which prevents leaves shading on each other, had more CGR. Weed competition also caused about 39% reduction in Max.CGR (Table 2). In addition, CGR change trends in different sowing dates showed that in early growth season (30 to 40 days after sowing) in each three sowing dates because of low leaf area, increasing of CGR was slow. After this time on June 9 sowing date due to faster leaf area improvement and due to more photosynthetic activity, CGR increased faster than two other dates so Max.CGR achieved earlier (75 days after sowing). In June 9, sowing date, because of lower LAD, downward trend of CGR began earlier. In the latest sowing date at fewer 100 days after sowing, CGR declined sharply due to leaves necrosis, early fall chilling, net photosynthesis reduction and high respiration severity (Figure 4). CGR changes among the different cultivars were similar (Figure 5). CGR changes curve affected by weed competition has been shown in figure (6). The effect of weed competition on crop growth rate, in compare with no weed presence and competition, is observable from 30 days after sowing. In weed free treatment, CGR increased with harsher gradient and in 80 days after sowing reached to its maximum, then Due to increase plant competition, reduction in light penetration into the canopy and yellowing of photosynthetic organs and nutrient transfer to grains, CGR was decreased. Medium CGR reduction in weed infested environment of Sugarcane also has been reported in two years experiment by zafar *et al.*, (2010).

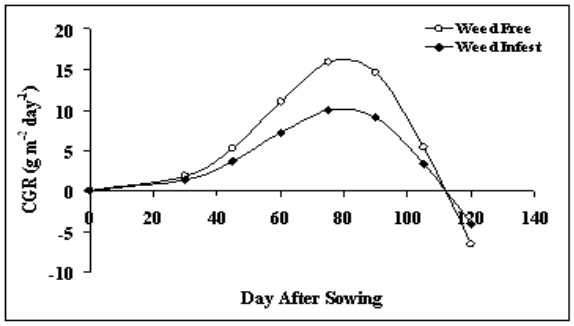

Fig. 6. Crop growth rate changes trends affected by weed competition.

The days from emergence to flowering

The effect of sowing date for the days from emergence to flowering (vegetative growth period) was significant ($p<0.01$) but cultivar and weed competition main effects and their interactions were not significant (Table 1). Results showed that vegetative growth period significantly reduced by delaying in sowing (Table 2). Environmental temperature enhancement, in result of delay sowing, caused acceleration in plant growth rate so that vegetative growth acceleration caused a reduction in vegetative growth duration and plant entered to reproductive phase faster. Grenz *et al*., (2005) also reported the acceleration of emergence to flowering duration of faba bean by sowing delay from December to January. Razmi (2009), by investigation of the effect of four sowing dates (September 23, October 7, 22 and November 5) on yield and yield component and some agronomic traits of canola also observed that days to flowering and maturity of canola was reduced by delay sowing.

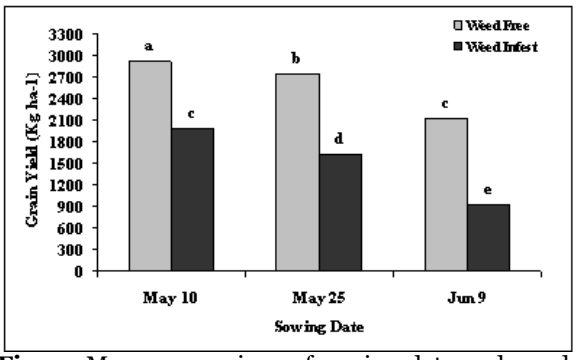

Fig. 7. Mean comparison of sowing date and weed interaction for white bean grain yield.

Duration of flowering

The effect of sowing date was significant ($p<0.01$) for duration of flowering but cultivar and weed competition main effects and their interactions were not significant (Table 1). Results showed that first sowing date (May 10) had maximum duration of flowering (10.16 days) and differences between second and third sowing dates were not significant (Table 2). Earlier vegetative growth initiation at first sowing date (May 10) caused a reduction in crop growth rate due to cold weather so that sowing to flowering duration increased and longer vegetative duration caused more flowering potential and resulted longer flowering duration. Razmi (2009) by evaluation of the effect of four sowing dates with 15 days intervals from September 23 on canola reported a reduction in flowering duration due to sowing delay. He assumed that conjunction of flowering duration with warmer weather at third and fourth sowing dates is the reason of flowering duration reduction in compared to first and second sowing dates.

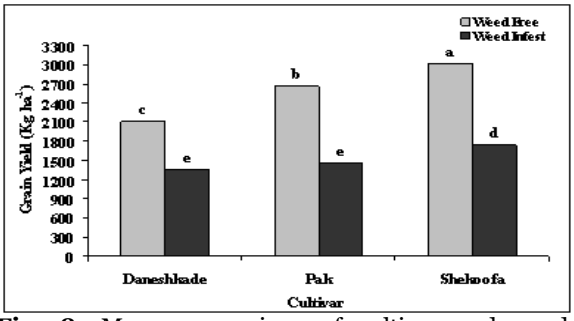

Fig. 8. Mean comparison of cultivar and weed interaction for white bean grain yield.

Grain yield

It is observed that the effect of each three treatments and interaction of cultivar and weed competition as well as interaction of sowing date and weed competition were significant on grain yield (Table 1). According to mean comparison the interaction of planting date and weed competition on grain yield it is observed that, the highest grain yield (2913 kg ha^{-1}) was seen for first sowing date under weed free condition and its lowest (1627 kg ha^{-1}) was seen for the weed free in third sowing date (Figure 7). These results also showed that 30 days delay of sowing (in compare with the first sowing date) in weed free situation caused 27% reduction in yield but in weed presence (no weeding), this delay caused 53% reduction in yield (Figure 7). Therefore it is obvious

that at the first sowing date in addition to increased white bean growth season duration and no conjunction with cold weather at the end of growth season, in the early season due to low temperature is coincide with lower weed density. Larger LAI, CGR and plant height were responsible of grain yield enhancement at first and second sowing dates. Khalil *et al*., (2010) explained that weaker growth, shorter grain filling and maturity duration, reproductive node reduction and decreasing of pods per plant reduced yield in delayed sowing date. Bastidas *et al*., (2008) reported that 45 days sowing delay of soybean (in compare with the first sowing, May 1) caused 745 and 1950 kg ha^{-1} grain yield reduction in first and second years respectively. Abbas *et al*., (2010) by evaluation of three sowing dates (November 8, 16 and 24) and *Emex australis* weed density (0, 1, 2, 3 and 4 plants per pot) reported that maximum fertile tiller number, thousand grain weight and grain yield of wheat were achieved at the first sowing date and without *E. austarils* weed and by delayed sowing and increased weed density the number of tiller reduced significantly due to tillering duration reduction and limited tiller production.

Mean comparison of interaction between cultivars and weed competition showed that the highest and lowest grain yield was related to weed free Shekoofa cultivar (3057 kg ha^{-1}) and weedy Daneshkade cultivar (1357 kg ha^{-1}) respectively (Figure 8). Minimum yield reduction (35%) as affected by weed competition was for Daneshkade cultivar due to its runner vegetative habit and covering the soil surface so that weed growth prevented. However, Pak cultivar due to its erect vegetative habit showed the highest yield reduction (45%) affected by weed competition (Figure 8). Indeed, Shekoofa cultivar because of its higher yields in both weedy and weed free situations was more favorable in compare with two other cultivars. Dihma and Eleftherohmorinos (2005) illustrated that the existence of wild oat with 120 plant m^{-2} density reduced the yield of different barley cultivars (8-67%) and early-maturity cultivars in weed competition situation produced grain yield more than medium and late-maturing cultivars, but their yield did not have significant difference in weed free condition.

Conclusion

Results of this research showed that in Semirom Iran, early sowing of white bean in May caused high yield due to longer growth duration, lower weed competition and higher crop growth rate and Shekoofa cultivar had the highest yield, among the investigated white bean cultivars, in this region.

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